SCADA SYSTEM OPTIONS FOR THE OILFIELD

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INTRODUCTION

The purpose of this paper is to share the authors' experiences in applying SCADA technology to the oilfield. This paper discusses some currently available SCADA technologies, how SCADA technology is typically applied to onshore oil and gas production, and the practical considerations of implementing oilfield SCADA. This is based on the authors' experiences as control system engineers in oil and gas producing operations. The intended audience is people familiar with onshore oil and gas production operations.

The manufacturers mentioned in this paper do not represent all of the available devices on the market, nor are they necessarily the best, but are included as examples from our experience that have been popular in the oil patch and that the reader might find familiar.

Topics covered in this paper are:

- RTUs including Electronic Flow Meters, Pump off Controllers, PLCs
- Human/Machine Interface (HMI) options
- Communication protocols (Modbus, Ethernet, others)
- Communication pathways (Wireless, Cable, Fiber Optic)
- Project economics
- Project implementation strategies
- System purpose vs. reliability
- Maintainability
- System integrator services

OVERVIEW OF OILFIELD SCADA

SCADA is an acronym that stands for Supervisory Control and Data Acquisition. SCADA has its origins in the power industry, where it is used for system wide supervisory control and metering over distribution systems.

Supervisory control relates to higher level control of systems of lower level controllers. For example, in a system of gas gathering lines, local controllers would control the flow and pressure at booster compressor stations, while the SCADA system would provide the setpoints for these parameters based upon the demands of the system and status of the various boosters, supply points, and delivery points. For this reason, it is not unusual for the responsiveness of the SCADA portion to be very slow when compared to the local controllers. The available technologies limit the ability of a SCADA system to respond to real time control needs. This is also not the purpose of a SCADA system since true SCADA is supervisory in nature. A PLC connected to a PC-based MMI is a control system, but not necessarily a SCADA system.

In the oil patch, the data acquisition portion tends to be emphasized. Examples of data acquisition include alarm monitoring, production data gathering, collecting pump off controller cards, and tank level monitoring. Again, due to the slow response of the SCADA system, data seen by an operator might be several minutes old. The data collection portion of a SCADA system typically stores historical data to provide trending capabilities. The database is also sometimes used to feed other company information systems such as those used for accounting, reservoir engineering, and subsurface engineering.

Typical applications of SCADA in the oilfield include:

- Collecting volume information and audit trail information from custody transfer meters.
- Collecting data from pump-off-controllers
- Monitoring production facility alarms and rates
- Monitoring injection facility alarms and rates
- Automatic field shutdowns on facility upsets
- Automated well testing
- Automated injection well control
- Electric power consumption monitoring

HISTORY OF SCADA IN OIL PATCH

Oil patch SCADA most probably has its origins in off shore applications. Offshore wells and production facilities which were not always manned were required to be monitored and controlled somewhat from safer locations on shore, or on larger platforms. Today, sophisticated SCADA systems permit operation of complex offshore facilities in bad weather conditions after the crew has been evacuated.

Pipelines have been using SCADA systems for many years to help manage remote metering and pumping facilities. Communications have evolved from hardwired lines to company-operated microwave networks along the pipeline right-of-ways, to fiber optics, leased lines, and satellite communications. Over the last few years, some gas pipeline and processing companies have been using SCADA systems to automatically gather information from the many custody transfer points in their extensive gathering systems. With expertise gained in pipeline operations, and technology developed for pipelines, oil companies have been able to migrate the technology to production applications.

As commercial radios and mass produced general-purpose remote terminal units (RTUs) became available, SCADA began to have an economic appeal in on-shore operations. Appearing first in regions with hard to reach locations, either due to climate or geography, SCADA quickly spread to all fields as a means of reducing windshield time, and responding to the most mission critical events first. Tertiary recovery projects in the early 80's made use of SCADA systems for injection metering and control, and for automated well testing.

In the continental US, as beam lift wells began to demand local controllers for pump-off control, microprocessor technology quickly responded. As this processing power began to be placed at beam lift wells in large quantities, it was not a large incremental cost to add telemetry capabilities. Now the pump off controllers were also acting as RTUs to a field-wide SCADA system.

ELEMENTS OF A SCADA SYSTEM

Refer to Figure 1.

RTU – Remote Terminal Unit. The electronics at the remote site that collects data and/or performs local control.

Communications – The communications system is the heart of a SCADA system. It is, after all, a Data Acquisition system. Some method of gathering data from a multitude of sources distributed over a wide area is usually required. Typically, in the oilfield, some type of radio communication is involved.

Host – Communication interface to the RTUs and repository of data.

HMI – Human/Machine Interface, the HMI is the operator's window to the process. HMIs may be as simple as a panel board with lights indicating wells which are down. Conversely, they may be complex graphical interfaces with animated trends, animations and live video of operating components, and voice alerts. The ubiquitous personal computer, with its low cost and great versatility, is rapidly becoming the HMI of choice. Even the industrial plant floor custom interfaces tend to have a PC inside, with a few notable exceptions.

Callout Systems – alerts operators to alarm conditions typically via radio, pager, or telephone.

Company Enterprise Systems – company databases used for accounting, engineering, and management. Usually on a server on the company LAN or on a mainframe computer.

RTUS (REMOTE TERMINAL UNITS)

The Remote Terminal Unit (RTU) is the portion of a SCADA system which actually senses inputs, and in some cases, sets outputs for control purposes.

The classic RTU has little if any computing ability, but reads and writes I/O under the direction of the SCADA host. Example: well testing in the early 80's typically consisted of a dumb RTU at a test facility communicating with a host computer, typically a mainframe or mini computer at a central location. The RTUs had no local control capabilities. Wells were switched in or out of test when directed by the SCADA host. The RTUs collected test meter information and alarms and passed the information directly to the host for processing.

Since memory and processing power have become so inexpensive, the classic "dumb" RTUs are rare. A few of these legacy systems are still in operation but are being gradually replaced with newer technology as replacement parts become more difficult to obtain. Typically the processing power required to permit communications using a modem protocol is also sufficient to perform local control functions.

A very common RTU in the oil field is the Electronic Flow Monitor (EFM). These devices can gather data, perform flow calculations and totalizations, and in some cases, provide limited local control. EFMs are employed at well test facilities, tank batteries or gathering stations, allocation meters at producing gas wells, custody transfer, and intermediate pipeline locations.

There are a variety of EFMs are the market which serve as standalone units or as RTUs in SCADA systems. These devices are usually solar powered, and are configurable (vs. programmable) for the flow conditions. They use industry standard flow calculations and store an audit trail and are generally acceptable for custody transfer. They typically have power connections and extra space internally for installing a third-party radio. A few are discussed here which are currently popular in the oilfield:

- TotalFlow (ABB) - These are quite capable of computing flows of complex gas and liquid compositions, and provide historical data which can be polled from the SCADA host. They are available with their own propri etary host software and protocol, and can communicate using a Modbus compatible protocol.
- Omni Flow Computers, Inc. – The Omni flow computers are highly programmable devices capable of various flow computations, as well as local control of multiple loops. Communications with various protocols are also afforded.
- Daniel Industries – A variety of EFMs are available from Daniel (Emerson Electric). The Spectra 100 is a small, low-power single-run flow meter that is capable of radio or modem communication with Modbus or other protocols.

There are also some general purpose RTUs available to the oil field, with specialized flow monitoring capabilities. Some examples:

- Automation Electronics – makes microprocessor based RTUs with custom ROM chips that allow discrete and continuous control, as well as flow computation and historization features. These RTUs are made to order, and include custom proprietary software.
- Bristol – makes a variety of data concentrators, programmable controllers, RTUs, and EFMs. With robust programming languages and custom software available, they are often employed as RTUs in the oil patch. They can communicate via proprietary or open communications protocols.
- Fisher – The ROC (Remote Operations Controller) is a popular programmable RTU used for flow metering and local control.

Pump Off Controllers (POCs) determine the pump fillage of beam lift pumps, and turn the well on and off accordingly to optimize production and prevent fluid pound. This is an attempt at a more adaptive method than the percentage timer used on many pumping wells. Due to the high sampling rates required, pump-off-control is almost exclusively performed in special purpose devices, rather than off-the-shelf PLCs or RTUs. Once pump-off-controllers became common in the oil patch, the temptation to add telemetry to those sites was too strong to resist. Originally, these communicated only via their own proprietary system protocols to a proprietary software packaged on the host computer. Market pressure is forcing POC manufacturers to communicate via open protocols such as Modbus or to provide communication drivers which allow the use of general purpose SCADA software for the host system.

POC systems are probably the largest oilfield SCADA systems. An oilfield using POCs will typically have one at every pumping well, which might mean several hundreds of units on the SCADA system. When property utilized, a POC SCADA system can be used by well analysts to proactively manage pumping wells. A number of down hole problems can be detected early by studying changes in pump cards over time (admittedly there is some art to this outside the skill set of the authors...it takes an experienced well analyst with time and patience to sit in front of the SCADA host daily). Wells can be remotely turned on or off by operators. The systems can be used to automatically shut off wells during upset conditions at tank batteries. Popular pump-off controllers with SCADA capabilities are D-Jax, Baker, and Lufkin (selling the former EDI, Delta-X and Nabla systems).

Programmable Logic Controllers (PLCs) have grown in capability and dropped in cost to the point that most new SCADA implementations use them as RTUs. As RTUs, PLCs provide flexible I/O options, access to generally available open communications protocols, and are well supported by systems integrators and the original suppliers and manufacturers. As RTU/Controllers, PLCs have grown to include continuous and even advanced control capabilities as well as the ability to perform flow calculations. Local controls with setpoints and control parameters provided by the SCADA host are easily implemented using PLCs from Schneider Electric (Modicon and Square D brands), Rockwell Automation (Allen Bradley), Moore, GE Fanuc, and others.

PC based control systems are becoming more accepted as PCs have become more robust. A PC-based controller at a facility can serve multiple functions. It is the local controller, it is the local operator interface, it can be an RTU in the SCADA system, and it can also provide a window into the rest of the SCADA system from the remote site. It also has the advantage of having the development software on board so technicians aren't required to have a laptop to maintain the systems.

THE SCADA HOST AND OPERATOR INTERFACE

The SCADA host is the hub of the system which collects data from the RTUs and sends set point or control commands back to the RTUs. The host might be a PLC or a PC or a DCS system. The host database is sometimes used to feed production information to the company's central enterprise systems.

PLCs typically have communications hardware and software permitting them to serve as protocol converters to talk to a variety of RTUs. They have sufficient memory available to serve as a host for fairly large SCADA systems. Modem PLCs support complex data structures and are strong competitors even as host systems. The advantage of PLCs over PCs as a host system largely reside in mean time between failure (MTBF) and the fact that they are usually not used for other purposes by the operators. PLCs can be purchased in redundant hot-standby configuration that increase availability and overall system reliability.

One method of isolating the host system from the details of the polling method is the Data Concentrator. In these systems, an intermediate hardware or software element (typically either a PLC or a dedicated industrial PC with no monitor or keyboard attached) utilizes the communications method to the RTUs which is appropriate to the application and available bandwidth. This data is stored in a database, and made available at high speeds to more conventional communications drivers connected by high bandwidth means. Of late, this connection is more commonly a database query language, implemented over a LAN.

HMI (Human Machine Interface, also called OI or MMI, for Operator interface and Man Machine Interface, respectively.) Configurable panel-mount HMIs are sometimes used as the central operator interface on very small SCADA applications, however these are usually only used on local control panels. When used as the central HMI, a PLC is typically used as the host device, with the panel-mount HMI as an interface to the host PLC. Popular HMIs in the oilfield include Rockwell's Panelmate, and units available from Nematron, and Exor.

A number of PC-based HMI packages are currently employed in SCADA systems. One of the main driving factors in the move to PC based HMIs is the familiarity of the operator with the PC interface. These systems are capable of acting as both the central SCADA host and the operator interface. Some of the more recognizable names are WonderWare InTouch , Intellution Fix , and RealFlex . There are many others, and each varies with respect to the others in the amount of automatic supervisory control available. WonderWare's Factory Suite for example, includes InControl which provides real time control at the PC level. This exceeds the requirements of most systems for Supervisory Control. One package that has specifically targeted the oilfield is the CASE system. This system provides communication to most popular POCs, and can interface to communication drivers for PLCs and EFMs as well. It has components to provide supervisory control and data collection for well testing, to handle production facility alarm monitoring, and to perform production allocation tasks. It's open database can interface to other popular HMIs to provide graphical interfaces for facilities.

The trend toward standardization in PC software has made control elements more available to HMI software. ActiveX controls and OLE (Object Linking and Embedding) for Process Control have facilitated the integration of complex control actions with otherwise "dumb" HMIs. In addition, database standards such as ODBC (Open Data Base Connectivity) allow control programs to have access to the read/write databases for the telemetry system. Obviously, this permits much more flexibility for automation in the oilfield than was previously available. This is not without drawbacks however. Previous systems tended to come from a single source or be custom applications from the ground up. If something did not function properly or needed to be modified, there was usually a single source to which to turn. Now, bits and pieces can be put together with the ultimate responsibility resting on the project engineer, rather than any one of the myriad suppliers of the software.

Clever engineers have taken advantage of this standardization by using standard application software such as Excel to provide simple interfaces to the SCADA system. Excel and other windows applications can directly request information from the communication drivers on the PC. This information can be displayed in spreadsheet form or even with simple graphics in Excel. With a communication driver loaded on a host that is tied to the company network, engineers in the office can create their own custom spreadsheets that pull real-time data from the SCADA system host.

A technical challenge with many of the generalized, non-SCADA specific HMIs has to do with the communications software. This software, commonly referred to as a "driver" provides the translation to and from the SCADA communications protocol. Most of the off-the-shelf drivers poll in a round-robin method. Periodically requesting all available data, and writing such data as may have been changed at the HMI on a by-exception basis. Custom solutions are therefore required to perform bandwidth intensive tasks, such as gathering historical data from a flow computer, or dynamometer data from a pump-off controller. Also, report by exception from the field RTUs is generally not supported. To solve these problems, third party drivers were created, taking advantage of the capabilities described in the previous paragraph. Additionally, legacy systems such as Exxon's CAPS, and Amoco's SAMS present a challenge to integrating the new technologies. The key question in implementing such a system is whether your company has the computing resources to support and maintain it.

In today's oilfield SCADA systems, one of the operator interfaces one may encounter is the processing plant distributed control system (DCS). In today's tertiary recovery fields, a processing plant with a highly automated control system is usually associated with the producing field. Often these systems already have interfaces to provide reporting and telemetry to management at the enterprise level. The increasing commonality of the technologies employed are making the marriage of oilfield SCADA to DCS more feasible. A variety of gateways are available to allow modem DCS' to communicate via common SCADA protocols. Another direction being taken in the last five years or so is to make a common database between the SCADA system and the DCS. In this way, the DCS MMI is capable of displaying data obtained via Ethernet from the SCADA polling master, for example.

Hybrid systems have a lot of the best of both worlds. These systems incorporate both an HMI and a PLC-type controller into a DCS-type system. From a configuration standpoint, they offer the advantage of a single database for HMI and control programming. From a SCADA standpoint, they have the advantage of being based on personal computer platforms, which opens them to non-proprietary communications means. Many of the popular Hybrids, such as Delta-V , and Plantscape , are based on Windows NT HMI platforms. This should facilitate the merger of the off-the-shelf drivers from existing MMI systems to these new systems.

CALLOUT SYSTEMS

Many methods exist for calling out alarms:

- SCADA system terminals have been placed at answering service offices. When an alarm appears on the terminal, the answering service calls the operator on duty.
- Automated phone dialers (autodialers). These dedicated systems can be hardwired to RTU I/O or can communicate digitally to a computer or RTU. These systems can be configured to call operators when an alarm occurs. Typically several phone numbers are configured into the system. When an alarm is detected, the machine proceeds to call everyone on the list until someone answers and acknowledges the alarm. Typically an answering service is included on the list so that a human takes over if the machine fails to reach someone. The machines can be programmed to dial pagers as well as telephones. They are sometimes even set up to call out via the field voice radio system. Low-end systems have pre-recorded messages (like "Alert Condition 1 Exists!"), while others allow you to record you own messages.
- Paging systems are available that can cover a plant or field. When the host detects an alarm, it can page an operator.
- Software is available to run on a host computer to let it act as an autodialer.

PROTOCOLS

The communication protocol is the "language" that the electronic devices use to communicate with each other. Poplar examples include Modbus, Data Highway, Ethernet, and others. There are two types of protocols: master/slave and peer-to-peer.

Master/slave protocols are used in two different ways: polling and report by exception.

In a pure master/slave arrangement, the host is typically the "master" which polls the "slave" RTUs one at a time to read or write information. An RTU can only speak when spoken to. Most radio telemetry SCADA systems in the oilfield use this "round robin" polling technique. In this way, each RTU gets polled for all of its data in a sequence. There are varying approaches to retries and failures due to communications, but this is a simple and reliable means.

The polling method has the advantage of determining whether and RTU is down, as it will fail to respond to its poll. The disadvantage of round robin is the time taken to poll ALL of the data in a large system. For data intensive applications such as Pump Off Control, this is unacceptable when the system is also used for facility alarms. Modified custom polling systems, which could provide more data on demand, were developed.

Report by Exception – SCADA systems currently implement two major variations of report by exception. One **is** a combination of polled response, in which the master polls each station in turn to see if anything has changed of note since the last poll. If the RTU responds in the affirmative, then the changed data is polled for by the host. Another method is to turn the master/slave relationship around. The host will simple sit quietly and await unsolicited messages from the RTUs. When alarm or change occurs at a remote site, the RTU sends an unsolicited message to the host. This method has the fastest response time to alarms. This is not without cost, however. If an RTU fails, the host system will not know. Also, collisions are possible, with multiple RTUs wanting to send data at the same time. This is likely to happen in cases such as a fieldwide power failure where all RTUs call in at once to report a power fail at their site or if the pipeline company shuts down the gathering system and all sites call in to report low flow or high pressure. Variations of report-by-exception abound, of course. There are timed systems in which clocks are used to ensure that RTUs only use certain times in order to avoid collisions. In some systems, a certain portion of each time period is utilized by the host for a short "health check" poll of all of the RTUs. Obviously, the more complex the method used, the more customized and less portable to other off-the-shelf systems it will be.

One of the most popular master/slave protocols in oilfield SCADA is Modbus. Modbus is a simple but effective protocol originated by Could-Modicon (now part of Schneider Electric) which comes in two flavors. Modbus ASCII is a seven-bit protocol which can be read on simple terminal equipment. The eight-bit Modbus RTU is more commonly employed in SCADA systems since it takes half as many bits for a message as Modbus ASCII. Modbus provides some error checking, as well as efficient packaging of data for a master/slave system. Modbus does offer some serious limitations, however. Most notably, it is limited to less than 250 RTU addresses. Vendors have come up with several work-arounds and extensions to the protocol to solve this problem, but they violate the standardization and can limit the connectivity to other "Modbus compatible" equipment. Be careful when buying a "Modbus" capable device...it might not be compatible with other "Modbus" devices if it is a non-standard or incomplete implementation of the protocol.

Another communications method which is rising in popularity in the oil field is peer to peer. Examples of poplar peer-to-peer protocols include Data Highway, Modbus Plus, and Ethernet (TCP/IP). In a peer to peer network, nodes may communicate directly to one another, without a master soliciting the communications. The complexity of such a communications system was once daunting to the systems integrator, but commercially available wireless LAN (Local Area Network) products have simplified things somewhat. Most PLC manufacturers now directly support Ethernet communications to their CPUs or via a communications module.

One advantage of peer-to-peer communications is the ability of any one site to see information at any other site on the network. Another advantage is the bandwidth offered by peer-to-peer protocols which allows rapid exchange of large amounts of data. Peer-to-peer also readily supports report-by-exception.

A good example of a system that takes advantage of Ethernet communications is at Chevron's McElroy field in West Texas. This system utilized PC-based controllers at 27 production facilities all connected via wireless LAN. **A** central master station calls out and logs alarms and stores production data. On a peer-to-peer system, the master station is no longer required to be the hub of all activity on the SCADA network. If an operator at one end of the field receives an alarm from the other end of the field, he can stop by any facility and access the data for the facility that has the alarm. The bandwidth available on the wireless Ethernet LAN has also allowed them to include video monitoring of the sites, so an operator can actually pull up a real-time picture of a site from any other site.

With controllers all connected via Ethernet, it is tempting to want to connect these to the company WAN so that the information can be accessed from the office. It is a bad idea to directly connect the control LAN to the business LAN. You don't want your alarms waiting to get through the system while a technician is downloading a 200 page instruction manual from the internet. The two systems must be kept separate by installing a router that will only allow certain traffic to pass between the two. Only certain designated users will be able to cross the line to get to the control network. In fact, it is more typical to connect only the master station (or host) computer to the company LAN, so that control system data can only be accessed from that computer's database.

There are many other standard protocols that you will hear of. Protibus, Interbus, Hart, and Fieldbus are examples. These are primarily intended for communication from controllers to end devices, or between controllers and I/O systems. These types of protocols have application within a single facility, but not for the communication between RTUs and the host.

COMMUNICATION PATHWAYS

Traditionally, wireless Multiple Address Systems (MAS) using 450 MHz and 900 MHz radios have been the most common communications pathway for SCADA in the oilfield. These are relatively inexpensive, and work quite well in a contiguous field with little variation in the topography. There are some limitations, of course. Also, 450 MHz is a voice – priority band. Telemetry systems may be interfered with by plumbers talking on car radios. Fortunately, most oilfield applications are rural, and cell phones are replacing radio dispatch systems. The difficulty of obtaining and maintaining 900 MHz FCC licenses varies from year to year, and may be the constraining element in the implementation schedule of a new SCADA system.

Spread Spectrum technology uses the theory that "4 watts is 4 watts" even if spread out over a wide frequency spectrum. The efficiency of radio communications is limited by the signal to noise ratio. Spread Spectrum distributes the signal over a wide frequency spectrum, and utilizes high speed computing to eliminate noise that is not common over the same spread. Microelectronics have made this quite inexpensive. These systems have the advantage of being able to be placed in proximity to other similar systems, so long as there is sufficient lack of overlap in the frequency spreads being utilized. The primary advantage of using spread spectrum technology is that licensing is not required if the total power on a frequency is kept within limits set by the FCC.

In any radio system, distance and topography are an issue. Line of sight is the most obvious limitation. If there are obstacles, large towers or repeaters will have to be utilized. Large towers may require complex permitting issues, particularly near airstrips. In order to extend the range of a host around obstacles or for longer distances, directional antennae and repeaters may be used. Repeaters transmit and receive on separate frequencies, and relay information from one radio to another. The host system may not have line of sight to an RTU, but they both may have line of sight to a repeater on a nearby mountain. This same technology is employed quite effectively in voice radio communications. Off the shelf products abound.

A nationwide cellular communications infrastructure now exists. In all but the most rural locations, some form of cellular network can be accessed. This permits RTUs to utilize this communications method. Cellular Modems, as well as automated voice callout systems can use this technology. The cost of operating these systems still limits it largely to infrequently polled, or report by exception schemes. (And don't forget to cancel the cell-phone account if the RTU is permanently taken out of service...)

In a small contiguous field, direct cable is often practical. It has the advantage of very high bandwidth. The disadvantage is largely in obtaining right-of-way to bury cable throughout a field, or to hang cable in overhead systems. Overhead systems are very susceptible to lightning damage, however. One should be very cautious in using them, as induced voltages are quickly distributed throughout the system, damaging perhaps ALL of the connected RTUs. Buried cables are less susceptible, but good lightning protection and grounding practices are still necessary to ensure that any damage is localized. Also, buried cables may be damaged during pipeline, facility, and road construction activities. With advanced planning during a new project, money can be saved by installing buried cable when the gathering and injection system lines are installed.

When direct cable is used, the connection topology is quite important. A star topology, in which every RTU has a unique direct connection to the SCADA host, is the most reliable and fault tolerant over all, but very probably prohibitively expensive. A loop of wire passing from the host to one RTU, then the next, then next, and so on (Daisy Chain) may be fairly inexpensive, but any single failure will isolate the downstream RTUs. The loop can be closed back to the host to prevent any single break from disconnecting an RTU, but this system will also lose communications in the event of two failures in the cable. Another system with some of the advantages and disadvantages of both is the trunkline system. In a trunk system, one or more "trunks" a run through the field, with "branches" dropping off to the RTUs that are passed by. With radio technology and pricing being what it is today, unless VERY high bandwidths are required, radios usually become cost effective if the RTUs are more than 1000 feet apart.

Another technology which has matured in the last decade is fiber optic communications. This technology has reached prices comparable to coaxial copper cables, and reliable off-the-shelf fiber Modems abound. Newer RTUs and PLCs are sometimes equipped with Ethernet fiber optic ports. Fiber allows almost absurd bandwidths, without the electrical interference and lightning damage problems inherent in electrical cable. Fiber optic cables can therefore be hung on utility poles with the power distribution system.

VSAT (Very Small Aperture Terminal) satellite systems, such as those used by large retail distribution chains, have been used with success in the oilpatch. They allow high bandwidth, and virtually unlimited distance between the host and the RTU. In a typical VSAT system, data is transmitted by a relatively weak transmitter to a satellite in geosynchronous orbit. There, it is retransmitted to an Earth station with a larger antenna and more powerful transmitter. The signal is then repeated to the same or a different satellite where the host, another VSAT, receives it. The most expensive element of these systems is buying time on the communications satellite. With the recent economic failures of satellite cellular companies, the cost situation of some type of satellite communications may well improve soon. Due to the cost difference between VSAT and other technologies, it is typically not employed where line of sight radio is an option. However, in pipeline SCADA, or for very remote well fields it is often the only viable option.

NEAT AND NIFTYS

There are some technologies that are available but we have not yet seen utilized in the oil patch. These technologies might lend themselves well to oilfield operations, however, where they are economically justified:

- With digital cell-phone access to internet information, data and alarms from a host computer that is internet connected could be accessed via a digital cell-phone in areas where services is available.
- PLC manufacturers are beginning to provide "web enabled" devices. CPUs or modules that are web-enabled have embedded HTML web-pages that can be configured to display process information, or controller diagnostics. If these are accessible from the company network, then anyone on the network with a standard web browser can see the information.

PROJECT CONSIDERATIONS

Economics – Obviously, SCADA systems are subject to project economics. While capital costs of systems are dropping rapidly, a robust SCADA system of any size is still an expensive undertaking. The economic drivers to SCADA include:

- Reducing "windshield time"
- Reducing equipment downtime
- Reducing environmental impact of upsets through faster response
- Maximizing operating profitability by coordinating assets
- Reducing downtime through faster response and better preventive maintenance data
- Maximizing production by providing better engineering data for reservoir work (especially in tertiary recovery applications)
- Improving utility contracts by managing curtailable power situations and by trending electrical load information
- Improving management decisions by providing better data faster

Obviously, in each case, the return on investment is a unique calculation to each company and field situation.

To get a true picture, it is also highly important to factor maintenance into the project economics. Spare backup equipment must usually be purchased and included in the initial capital cost. Instrumentation requires routine maintenance. Host PC software is typically upgraded periodically. Lighting and power surges damage RTUs. If a project life is more than 5-years, assume that some significant percentage of the system will be replaced or upgraded over the life of the system and include that cost in the project economics. For a very large system, the salary for one or two full-time technicians might have to be included. Maintenance tools must be considered as well. PLCs and most RTUs require a laptop and proprietary programming software that can cost thousands of dollars. Oilfield use laptops should be ruggedized and have screens readable in direct sunlight, which are even more expensive. Technician and engineer training might be required at vendor schools in exotic locations.

PROJECT LIFE

At the outset, the engineer must realize that the SCADA system installed will be obsolete before startup. Fortunately, unlike the auto industry, it is not necessary to shave seconds off of automated processes each year to stay ahead of the competition. An obsolete SCADA system may serve for a decade or more. Some legacy systems have been in use for 20-years or more and are continuing in service with upgraded field hardware.

The determining factor will be the technical expertise of the operating company, or the availability of contract or supplier expertise. For this reason, there are two strong trends in the oil patch. Among some of the larger companies, with substantial MIS departments, proprietary systems developed in-house are adhered to. In this way, operating companies are not at the mercy of technological "improvements" made by their suppliers. Another common approach is to use widely installed off-the-shelf products. The larger the installed base, the less likely it is to be "orphaned" by the supplier. In this age of mergers and acquisitions, it is difficult to guess which devices and software products will be supported in ten years. For this reason, the large customer base provides leverage to ensure that support continues. Fortunately, in a SCADA system, it is not so important that the actual devices initially installed continue to be supported. As long as new devices and software can COMMUNICATE with the existing system, a gradual migration to newer technology may continue throughout the life of the project. As older systems become unserviceable, newer systems using compatible communications protocols may be placed in their stead. For this reason, perhaps the most important decision the engineer can make is the selection of a communications protocol.

IMPLEMENTATION STRATEGIES

Purpose vs. Reliability (Availability) – When designing a SCADA system, the purpose of the overall system must be kept in mind. In order to make appropriate decisions regarding technology and cost, it is important to understand the availability and reliability requirements of the system.

Availability is defined as the percentage of time (usually expressed in days or hours per year) during which the system may be relied upon to respond to inputs or commands. In other words, how likely is it that the system is functioning.

Reliability is defined as the percentage of operations which fail. This is typically expressed in terms of lout of 10,000 or 1 out of 100,000. Sometimes this is shortened to "four zeros, five zeroes, six zeroes", etc.

The distinction between availability and reliability is subtle, but crucial in a SCADA application. Consider a polled system versus a report by exception system. In this example, the system has supervisory control requirements to shut off pumps on a pipeline when the downstream tankage is full. In the polled system, if the tankage RTU reports full, OR fails to respond to poll, the pumps are turned off. In the report by exception system, and **RTU** failure may go unnoticed. In the polled system, the reliability is higher, as the safe action will be performed more reliably. The report by exception system provides higher availability of the pumps, as they will respond to SCADA commands, even if the tank **RTU** has failed. Analysts may argue even about this example.

It is a very subtle topic, and one may become easily lost in discussions of semantics. For example, the availability of the pumps may be contrasted with the availability of the SCADA system. The relevant feature of this discussion to the one implementing a SCADA system is the careful study of your system's purpose. Is it crucial to fail safely for personnel protection, equipment protection, or environmental concerns, or is it crucial to keep the system availability and flexibility of response in place in remote, inaccessible locations, for example.

MAINTAINABILITY

Obviously, the maintainability of the system will be important. Does the operating company have the personnel to maintain, troubleshoot, repair and replace elements of the SCADA system? Are redundant RTUs, hosts, or radios required to permit servicing without loss of functionality? Are spares to be kept on-hand to reduce downtime or will you rely on the vendor's stock? Are the RTUs going to be repaired in-house or sent off for repair?

SYSTEM INTEGRATOR SERVICES

The authors are unaware of any systems suppliers at this date who provide turnkey SCADA systems from end device to HMI. Specific oil field expertise is required typically, as well as communications and database skills. From the DCS to the stand alone RTU supplier, good support is available for the products they provide. The SYSTEM responsibility remains with the end user, however. For this reason, as well as the rapidly evolving technologies, most producing companies, and some engineering and construction companies, turn to professional Systems Integrators. These consultants can help design the system, work with the vendors of the various components, and provide any configuration and custom hardware or software required to make the system work as a whole. Typically, these consultants are familiar with one or more of the common off-the-shelf platforms, but do not know the engineering and operating specifics of your producing oil field.

This profession is only now being recognized in certain states as an engineering function. Accordingly, professional certification is not required to enter this discipline as of yet. Vigilance in the selection and management of systems integrators is crucial to the success of a SCADA project. It is beneficial to structure projects so that the operating company will gain expertise in-house which is specific to the project being installed. Otherwise, they may be dependent upon that integrator for some time to come. Worse, they may be dependent upon certain individuals who worked on the project. Ensure that technical training on the maintenance, operation, and MODIFICATION for the future is provided and included in the project budget.

It is crucial that complete documentation and electronic copies of configuration and source code data is provided to the owner. Carefully study any contracts. Most suppliers and some integrators retain copyrights on their work. It is important that the owner understands to what extent elements of the SCADA system may be copied, modified, or used elsewhere. On the other hand, if the owner makes proprietary information available to the integrator, steps should be taken to ensure that it is not communicated to competitors or used otherwise to the detriment of the owner.

When seeking an integrator for your project, first identify potential candidates, solicit their company resumes, contact their references and select three or four qualified bidders. If you are doing several projects, it is advisable to try to build an informal working relationship with one integrator who will learn how your company does things and becomes part of your team. For your project write a defined scope of work for the integrator to provide a bid or an estimate. Things that might be in the integrator's scope include:

- Control philosophy – general statements of system purpose, reliability requirements, etc. An integrator can help lead your engineering team in putting this together, but your company's involvement is crucial.
- Cause and Effect Schedule.
- Equipment Selection and specification.
- Procurement.
- Control panel design and fabrication.
- Instrument specifications.
- Programming.
- On-site construction and startup assistance.
- Operator and technician training.
- Documentation.

Along with this scope of work, it is important to provide any company specifications and standards which you expect the integrator to follow, as well as calling out any industry standards which must be followed.

The following is a sample of a step by step SCADA system implementation process:

- Determine the need for the SCADA system. What capabilities are required which are not already present'? What needs to be improved?
- Determine the economic justification for the SCADA system. What is the expected rate of return for the investment? What capital cost would be permitted for the desired return?
- Develop preliminary system design. How many sites? How many I/O per site? Where will the data be required to be displayed? Where will control be initiated? What communications throughputs will be re quired?
- Select communications method and basis layout of communications system. As certain number of repeaters, hubs, etc. What brands of RTUs and host systems provide the required features?
- Perform a cost comparison and analysis of the preliminary system and likely candidates for the RTUs and host system.
- Review proposed system against economic justification for a go/no-go decision.
- Develop a list of qualified integrators and suppliers.
- Prepare a request for quote for the implementation of the system.
- Bid the implementation.
- Have the successful bidder provide a detailed system specification based upon your RFQ.
- Review the detailed design documents as they are created.
- Review and approve a factory acceptance test plan. This should prove communications, logic, and displays, at a minimum. Insist on demonstration where possible. This will save you troubleshooting time at startup.
- Obtain operating and maintenance instructions as part of the integrator supplied package.
- Attend factory acceptance test.
- Receive job books with vendor data and all detailed drawings and document PRIOR to commissioning.
- Provide oversight and support during loop checks and commissioning.
- Receive copies of any as built drawings, electronic copies of code, drawings, and relevant documents.

REFERENCES

'"PC Based Control **SCADA** via Wireless **LAN"** article by Ray Garcia and Thad Gailey.

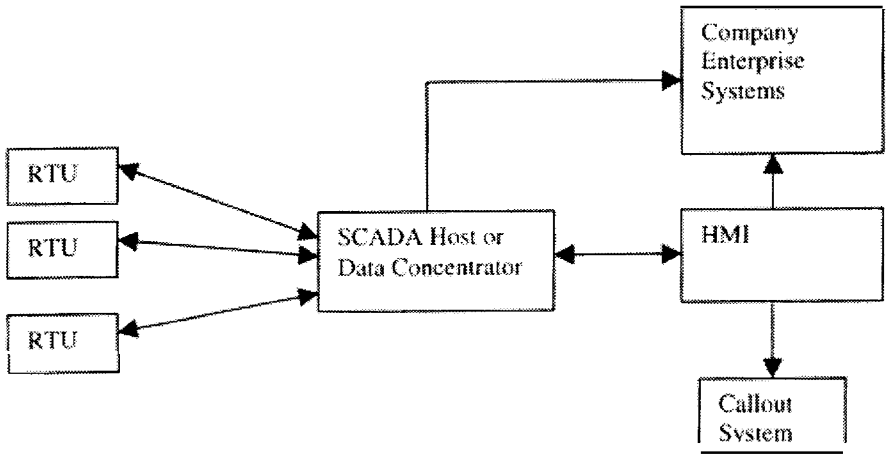

Figure 1 – Classic **SCADA** System